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IRON-ABSORPTION BAND ANALYSIS FOR THE DISCRIMINATION OF IRON-RICH ZONES

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15. Supplementary Notes

16. Abstracts

Most major rock units and unaltered and altered areas in the study area can be discriminated on the basis of visible and near-infrared spectral-reflectivity differences recorded from satellite altitude. These subtle spectral differences are detectable by digital ratioing of the MSS bands and subsequent stretching to increase the contrast to enhance spectral differences. Hydrothermally altered areas appear as anomalous color patches within the volcanic-rock areas. A map has been prepared which can be regarded as an excellent reconnaissance exploration map, for use in targeting areas for more detailed geological, geochemical, and geophysical studies.

Mafic and felsic rock types are easily discriminated on the color stretched-ratio composite. The ratioing process minimizes albedo effects, leaving only the recorded characteristic spectral response. The spectra of unaltered rocks appear different from those of altered rocks, which are typically dominated by limonite and clay minerals. It seems clear that differences in spectral shape can provide a basis for discrimination of geologic material, although the relations between visible and near-infrared spectral reflectivity and mineralogical composition are not yet entirely understood.

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C. Problems relating to progress:

Processing has been delayed for six new ratio images in which the same part of the ratio range of each ratio image is uniformly stretched. Such images should permit a valuable qualitative estimation of the spectral reflectivities of the surficial materials. Without relating film density to the digital number (DN) ratio value, comparison among the MSS bands for spectral reflectance differences is virtually meaningless. Histograms of DN value range of each ratio image will be available in the near future for selecting the most desirable stretch and ratio range for maximum enhancement.

Absolute spectral reflectivity cannot be determined from the MSS tapes until adequate data for calibration are available. Normalization is needed to minimize atmospheric effects and system calibration problems. Plans are underway for taking measurements and establishing standards.

Considerable time and expense have been spent in efforts to reproduce photographically the diazo color-ratio composite which represents the end result of several months of computer processing and analysis. Because subtle variations in color on the composite allow discrimination of geologic materials not possible on standard ERTS images or composites, faithful photographic reproduction of the true colors in the composite is essential. Unfortunately, the most important color used for discrimination of mineralized areas is green, one of the most difficult colors to duplicate photographically. Many other color combinations were tried in an effort to replace the green with a more easily reproducible color. However, no other combination of colors provides the discrimination capabilities that our original diazo color composite does.

Bringing all the images and geologic maps to a common scale has also been time consuming. None of the computer-produced transparencies are at a scale consistent with the geologic maps. As a result, they had to be projected onto an overlay of the playas taken from a geologic map at the desired scale. This procedure yielded less than accurate results, however; the photographic paper shrank in the drying process, and the paper on which the geologic map was printed was also found to be metrically unstable. Finally, a stable mylar overlay of the original geologic map was obtained as was dimensionally stable photographic paper. Even then, the scale of the resulting print was not uniform within the picture because the ERTS view of the earth has a slightly different geometry than a planimetric map. The same overlay unfortunately cannot be used to scale the standard ERTS images because the negatives are too dense. Several substantial delays in receiving work from the photographic laboratory also hindered progress.

The atmospheric correction procedure may need revising, as albedo effects are still apparent in the processed images. The topographic effects which are still evident, and which should have been minimized by this procedure, interfere with the discrimination of some rock types.

Results of computer processing of a second tape were not as good as those of the first tape, which was processed by a different computer laboratory. One of the band ratios is at a slightly larger scale than the others, making compositing impossible, and the stretches used are too small.

D. Accomplishments:

The week of August 11-18 was spent in the field examinging anomalous areas seen on a color stretched-ratio composite of half a frame of south-central Nevada. This composite (MSS 4/5, blue; MSS 5/6, yellow; MSS 6/7, magenta) provides the maximum enhancement for the available stretched-ratio images. An overflight made before work was done on the ground was useful in view of the large size of the study area. It was especially valuable over the Nellis Bombing and Gunnery Range in which field time was restricted and ground photography prohibited.

Major lineaments (>10 km) seen on an ERTS image mosaic of Nevada at 1:1,000,000 scale have been digitized using a grid base. Such values as mean length and dominant trend directions will be determined through computer analysis. Metal-mining districts for 17 different minerals have also been digitized to facilitate statistical correlation analyses. Computer programs are being set up for evaluating correlation of mineral occurrences with major lineaments and their intersections.

Spectra for two basalts, a limonitic area, and a playa have been determined from ratioing the MSS DN values. However, as mentioned previously, standards are needed for calibration purposes.

E. Significant results during the reporting period:

Work has been concentrated on the radiometric aspects of this project during this reporting period. Results of this study show that most major rock units and unaltered and altered areas in the study area can be discriminated on the basis of visible and near-infrared spectral-reflectivity differences recorded from satellite altitude.

These subtle spectral differences are not detectable through what have become conventional optical methods of analysis. Digital ratioing of the MSS bands and subsequent stretching to increase the contrast are necessary to enhance spectral differences which are manifested as slight variations in the slope of the spectra. Although the basic spectral differences are contained in the stretched-ratio images, color-ratio composites, especially combinations of three ratio images, appear to be the best means of display for geologic interpretation. The optimum combinations of ratios and colors appears to be MSS 4/5 (blue), MSS 5/6 (yellow), and MSS 6/7 (magenta).

Hydrothermally altered areas appear as anomalous color patches within the volcanic-rock areas on the composite. The anomalous colors range from green to brown; red-brown hues are present more rarely. On the basis of field checking from aircraft and on the ground on three separate occasions, all the green areas, except two, proved to be hydrothermally altered. One exception is a ferruginous sandstone and siltstone. This observation is not necessarily negative, as similar deposits, such as the oolitic sandstone of the Clinton Formation, are major producers of iron ore. The other exception is a Tertiary mafic intrusive rock whose green-gray outcrops appear to be generally free from ferric iron surface stains. This still enigmatic area will be the subject of future coordinated petrographic and spectral analyses. Not all the green areas are limonitic, however. Some green areas, as well as all the brown and red-brown areas checked, are bleached argillized rocks which are essentially limonite free. Nevertheless, with the two exceptions mentioned above, all the anomalously colored areas examined are altered, although the brown and red-brown areas have not been checked in as much detail.

A map of the hydrothermally altered outcrops based on the above color-stretched ratio composite has been prepared. High-altitude photographs were used to delete alluvium which tends to have a green hue on the composite where stained by iron oxides. This map can be regarded as an excellent reconnaissance exploration map, for use in targeting areas for more detailed geological, geochemical, and geophysical studies. However, additional testing in other areas is needed to determine whether or not different types of alteration can be separated.

In order to evaluate this map further, the locations of known mines and prospects were plotted on the color stretched-ratio composite. Clusters of mines and prospects agree well with the distribution of the altered areas. In the Goldfield mining district, for example, very striking agreement is found between the anomalous green pattern and the map of the alteration zone by Jensen and others.[1/] Poorest agreement is in the southwestern part of the study area, where alteration is limited to relatively small vein deposits in pre-Tertiary rocks. Higher spatial resolution may be necessary for detailed mapping of these areas.

Mafic and felsic rock types are easily discriminated on the color stretched-ratio composite. Even the Thirsty Canyon tuff and flows, which have a very low albedo and which are indistinguishable from the mafic rocks on the standard and stretched images, can be distinguished on the composite. The ratioing process minimizes albedo effects, leaving only the recorded

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1/ Jensen, M. L., Ashley, R. P., and Albers, J. P., 1971, Primary and secondary sulfates at Goldfield, Nevada: Econ. Geol., v. 66, p. 618-626.

characteristic spectral response.

Some of the more important practical limitations of the composite include erroneous identification of basalts as felsic rocks where a good soil cover has formed, and a lack of discrimination thus far of basaltic and andesitic rocks. Vegetative masking of terrain can be troublesome, although light vegetation does allow measurement of the spectral reflectivity of the underlying geologic material.

Ultimately, with proper normalization using surface standards, it should be possible to derive relative reflectance spectra for the surface units which would provide a means of placing bounds on mineralogical composition. In the meantime, simple discrimination of rock units and altered and unaltered areas is possible using computer-enhanced MSS data.

The spectra of unaltered rocks appear therefore to be different from those of altered rocks, which are typically dominated by limonite and clay minerals. The shape of the spectra of these alteration materials is primarily affected by iron-absorption bands in the near infrared and the blue-green region of the spectrum and by water-absorption bands in the near infrared. These absorption bands are rarely present in the spectra of unaltered rocks recorded within the response range of the MSS. It seems clear, therefore, that differences in spectral shape can provide a basis for discrimination of geologic materials, although the relations between visible and near-infrared spectral reflectivity and mineralogical composition are not yet entirely understood.

F. Reports

Rowan, L. C., 1973, Iron-absorption band analysis for the discrimination of iron-rich zones: U. S. Geol. Survey open file report, 24 p.

Rowan, L. C., Billingsley, F. C., Gillespie, A. R., Goetz, A. F. H., and Wetlaufer, P. H., 1973, Discrimination of limonitic zones and of rock types using ERTS imagery [abs.] Geol. Soc. America, Abs. with Programs, v. 5, no. 7, p. 787.

Rowan, L. C., Wetlaufer, P. H., Billingsley, F. C., and Goetz, A. F. H., Using computer-enhanced ERTS MSS images [abs.]: Third ERTS Symposium Dec. 10-14, 1973, Abstracts, (NASA/Goddard Space Flight Center), p. 52.

G. Changes in operation:

None

H. Changes in standing order form:

None

I. ERTS Image Descriptor forms:

Attached

J. Data Request forms:

No changes

(See Instructions on Back)

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS		
	volcanics	playas	> 20% snow	important mineralized areas	Major fault zones	60 % cloud cover
1304-17495		x			x	
1304-17502		x				
1321-17442						
1307-18053				x		x
1307-18055		x		x		x
1307-18062	x			x	x	
1307-18064	x		x			
1308-18111		x				
1308-18113		x		x	x	
1308-18120				x		
1309-18165	x					
1309-18172						
1323-17553		x				
1323-17555		x				
1322-17594		x			x	
1322-17501		x				
1323-17535	x				x	x
1323-17544	x			x		
1323-17550	x	x		x		
1325-18060	x			x	x	x
1325-18063	x		x			
1324-17593					x	
1324-18000		x		x		
1324-18002				x		
1324-18005	x	x		x		
1326-18110		x				x
1326-18112		x		x	x	x
1326-18115				x		
1327-18164	x					
1327-18171						
1339-17441						
1340-17493		x			x	
1340-17495		x				

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	volcanics	playas	> 20 % snow	important mineralized areas	major fault zones	> 60% cloud cover
1344-18104		x				
1344-18111		x		x	x	
1344-18113				x		
1341-17533	x					
1341-17540	x	x				
1341-17542	x			x		
1341-17545	x	x				
1341-17551		x				
1341-17554		x				
1342-17592					x	
1342-17592		x		x	x	
1342-18001				x		
1342-18003	x	x		x		
1345-18163	x					
1345-18165						
1388-18111		x				
1388-18113		x		x	x	
1388-18120				x		
1389-18165	x					
1389-18172						

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